HEAVY ION TEST REPORT

SINGLE EVENT EFFECTS
TPS25940ARVCR
(DC2301)
2.7 - 18V eFuse with True Reverse Blocking and DevSleep Support for SSDs
From
Texas Instruments

TRAD/TI/TPS25940ARVCR/2301/ESA/JB/2308			Labège, December 4th, 2024
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Abbreviations and acronyms

DUT	Device Under Test
ESA	European Space Agency
LET	Linear Energy Transfer
RADEF	RADiation Effects Facility (Jyväskylä, Finland)
SEL	Single Event Latch-up

Abstract

The main objective of this test was to evaluate the sensitivity of the TPS25940ARVCR, a 2.7 – 18V eFuse with True Reverse Blocking and DevSleep Support for SSDs versus SEL.
The irradiation was performed at RADEF with a maximum LET of 38.8 MeV.cm²/mg.
The main conclusions are the following.

The SEL test was performed under SEL test conditions (see Table 6).

In SEL test configuration
Destructive events were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET tested during this test campaign.

1. Introduction

This report includes the test results of the heavy ion SEE test sequence carried out on the TPS25940ARVCR, a 2.7 – 18V eFuse with True Reverse Blocking and DevSleep Support for SSDs from Texas Instruments, susceptible to show SEL induced by heavy ions.

This test was performed for ESA at RADEF. Irradiations were performed from October 27th, 2023 to October 28th, 2023. During this test campaign, 3 samples were irradiated.

2. Documents

2.1. Applicable documents

[AD1] Technical proposal: TRAD/P/ESA/AO17950/AR/131222 Rev 0 dated 13/11/2022
[AD2] Irradiation test plan: ITP/TRA/TI/TPS25940ARVCR/WQFN-20/SEE/210923

2.2. Reference documents

[RD1] ESCC Basic specification No. 25100 Issue 2 of October 2014
[RD2] Datasheet: TPS25940x 2.7 – 18V eFuse with True Reverse Blocking and DevSleep Support for SSDs datasheet (Rev. A) dated 26/03/2015

3. Organization of activities

The devices were procured and delidded by TRAD. The testing board and testing software were developed by TRAD. Before the campaign the samples were checked-out and the test bench was validated at TRAD. The test campaign was performed by TRAD under ESA supervision. The next table summarizes the responsible entity for each activity involved in this project:

1	Procurement of Test Samples	TRAD
2	Preparation of Test Samples (delidding)	TRAD
3	Preparation of Test Hardware and Test Program	TRAD
4	Samples Check out	TRAD
5	Accelerator Test	TRAD/ESA
6	Test Report	TRAD

Table 1: Organization of activities

4. Parts information

4.1. Device description

The TPS25940 eFuse Power Switch is a compact, feature rich power management device with a full suite of protection functions, including a low power DevSleep™ mode that supports compliance with the SATA™ Device Sleep standard. The wide operating range allows control of many popular DC bus voltages. Integrated back to back FETs provide bidirectional current control making the device well suited for systems with load side holdup energy that must not drain back to a failed supply bus.
Load, source and device protection are provided with many programmable features including overcurrent, dVo/dt ramp and overvoltage, undervoltage thresholds. For system status monitoring and downstream load control, the device provides PGOOD, FLT and precise current monitor output. Precise programmable undervoltage, overvoltage thresholds and the low IQ DevSleep mode simplify SSD power management design.
The TPS25940 monitors V(IN) and V(OUT) to provide true reverse current blocking when V(IN) < (V(OUT) – 10 mV). This function supports swift changeover to a boosted voltage energy storage element in systems where backup voltage is greater than bus voltage.

4.2. Identification

Part designation	TPS25940ARVCR
Manufacturer	Texas Instruments
Part function	2.7 – 18V eFuse with True Reverse Blocking and DevSleep Support for SSDs

Table 2: Part identification

4.3. Procurement information

Package	20-WQFN
Date code	2301
Lot code No.	3009490CD3
Number of tested parts	3 irradiated samples

Table 3: Part procurement information

4.4. Sample preparation

5 parts were delidded, 1 sample was damaged during this operation.
A functional test was performed on delidded samples to check that devices were not degraded by the delidding operation.
Among the 4 delidded samples available for the test campaign, 3 were irradiated and 1 was not used.

4.5. Sample pictures

4.5.1. External view

The Figure 1 shows an external view of the parts. Left and right pictures are respectively the top and the bottom views of the package.

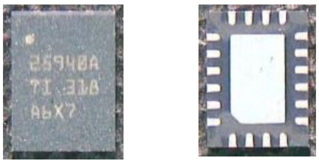

Figure 1: Pictures of the package

4.5.2. Internal view

Figure 2 gives an overview of the die. Figure 3 presents a view of the internal markings observed on the die (indicated by a red rectangle on Figure 2).

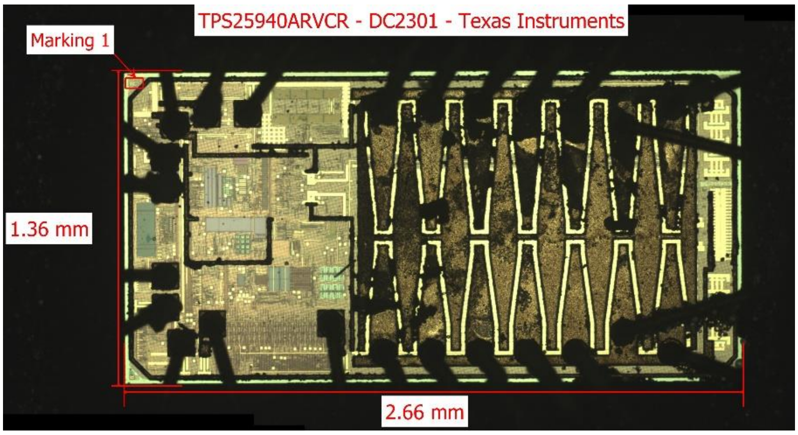

Figure 2: Picture of the internal overall view

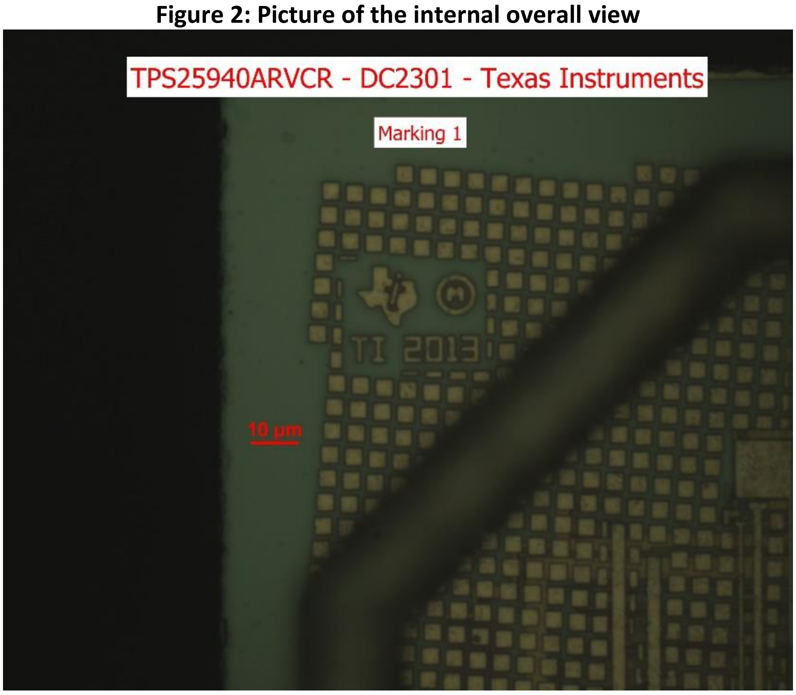

Figure 3: Picture of the die markings

5. Dosimetry and irradiation facility

5.1. RADEF heavy ion test facility

The cyclotron used is a versatile, sector-focused accelerator for producing beams from hydrogen to xenon.

Heavy ion irradiations are performed in a vacuum chamber with an inside diameter of 75 cm and a height of 81 cm. The vacuum in the chamber is achieved after 5 minutes of pumping, and venting takes also only a few minutes. Irradiations can also be performed in air, therefore the LET and the range is calculated according the distance between the collimator and the component.
The components can be fixed on a 25x25cm^2 aluminium plate which will be mounted on the linear movement apparatus inside the chamber. The DUT can be moved in the X and Y directions and also tilting is possible.

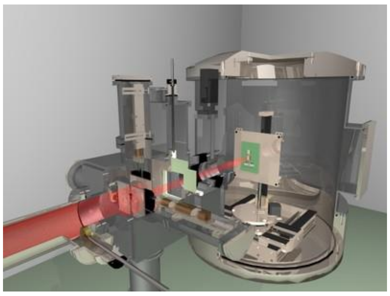

Figure 4: RADEF facility

A CCD camera with a magnifying telescope is located at the other end of the beam line to determine accurate positioning of the components. The coordinates are stored in the computer's memory allowing fast positioning of various targets during the test.

5.2. Dosimetry

To control and monitor the beam parameters, scintillation plastics connected to photomultiplier tubes are used as detectors. Four of such kinds of detectors are very close and placed around the edges of the beam. Detector can be moved to the front of the DUT and evaluate flux and homogeneity.
The spot size is 2 cm^2 and for special cases up to a diameter of 70 mm in vacuum. The Spot Homogeneity is ± 10 %

5.3. Beam characteristics

The beam flux is variable between a few particles $s^{-1}cm^{-2}$ and 1.5E+4 $s^{-1}cm^{-2}$ and is set depending on the device sensitivity. On special request, the users have the possibility to increase the flux up to 1E+6 $s^{-1}cm^{-2}$.
Characteristics of heavy ions available at RADEF during the test campaign are listed in Table 4 where heavy ions used for this test campaign are highlighted.

ION	Energy (MeV)	Range (µm(Si))	LET (MeV.cm²/mg)
$^{126}Xe^{44+}$	1446.48	105.71	56.8
$^{107}Ag^{37+}$	1714	158	38.8
$^{83}Kr^{29+}$	1358	185	24.5
$^{57}Fe^{20+}$	941	214	13.3
$^{40}Ar^{14+}$	657	264	7.2
$^{20}Ne^{7+}$	328	360	2.3
$^{17}O^{6+}$	284	481	1.5

Table 4: RADEF heavy ion list

6. Test procedure and setup

6.1. Test method

With respect to reference documents (see 2 Documents), runs were performed:

- Up to a fluence of 1E+7 cm^{-2} with only SEL monitoring.

6.2. Test principle

6.2.1. SEL test principle

A SEL is a permanent event that results from the activation of a parasitic thyristor structure creating low impedance conduction path in the device. The consequent high current can potentially damage the device, possibly even leading to its destruction due to overcurrent. A power cycle is required to correct this situation.

GeV is a specific equipment developed by TRAD to protect the DUT and to perform SEL characterization. The power supply is applied to the DUT through GeV which protects the DUT against over consumption. Indeed, GeV continuously monitors and records the current. A programmable threshold current is set above the nominal operating value of the supply current. During irradiations, if the current consumption exceeds the threshold during a defined “hold time”, a SEL is counted and the DUT is switched off during a defined “off time”. Once the event is defused, the power supply is switched ON again with the nominal current consumption expected.

Figure 5 shows a common SEL characteristic, with and without the GeV system protection.

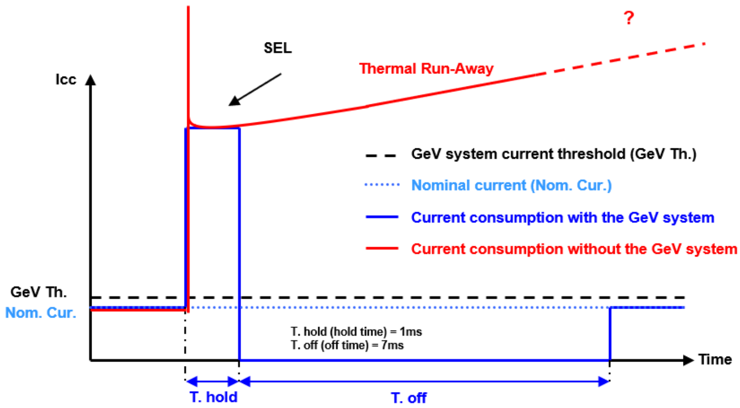

Figure 5: Common SEL characteristic

The SEL test was performed under SEL test conditions (see Table 6).
TRAD uses a dedicated system to heat and regulate the DUT temperature. The temperature is visualized and regulated from outside of the vacuum chamber during the irradiation.

6.3. Test bench description

6.3.1. Test bench overview

Figure 6 provides a global view of the test bench. It is composed by:

- A computer to control the test equipment and to record the SEE.
- A test board to bias and operate the DUT (schematic is shown in Figure 8).
- A power supply for the DUT and auxiliary components.
- A GeV System to protect the DUT, detect and record SEL.

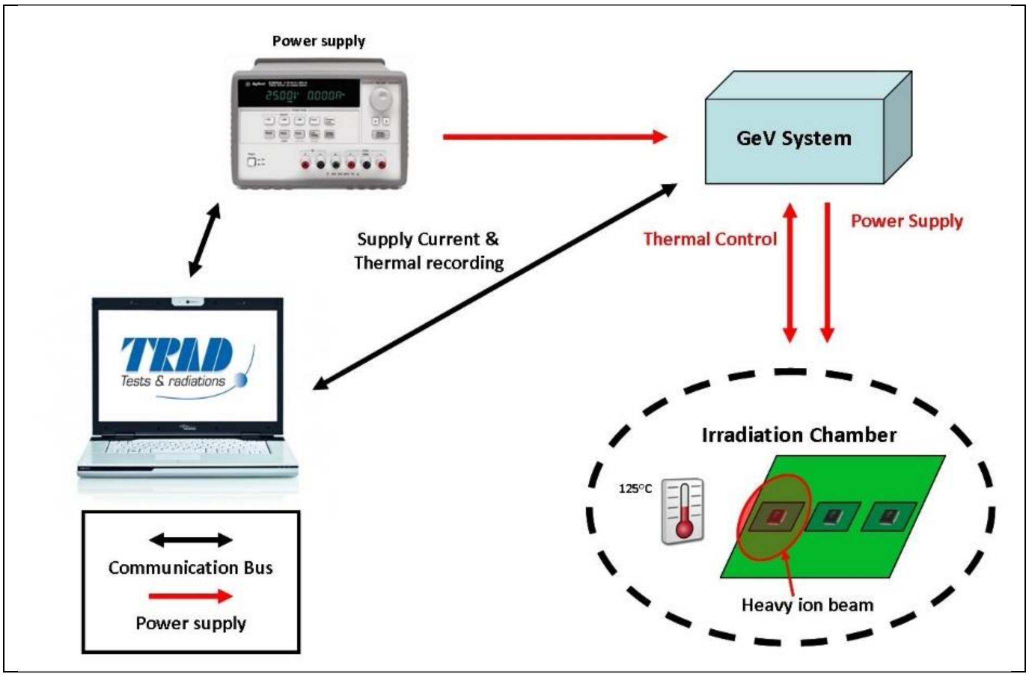

Figure 6: Test bench description

6.3.1. Heating system

TRAD has developed a specific heating system to heat and regulate the temperature of the DUT. Figure 7 shows a thermal image taken during the heating calibration of the DUT, the temperature of the die was set to 125°C as shown on the picture.

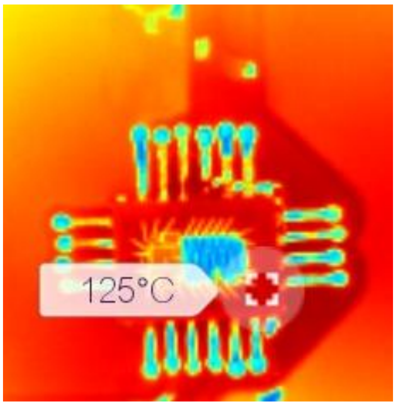

Figure 7: Thermal image of TPS25940ARVCR heated to 125°C

6.3.2. Test equipment identification

TEST BOARD	TRAD/TA1/I-L/TPS25940ARVCR/WQFN20/MF/2308
EQUIPMENT	SM-87; SM-96; GeV-3
TEST PROGRAM	TRAD_TI_TPS25940ARVCR_SEL-GeV_V10.spf

Table 5: Equipment identification

6.3.3. Test board description

The TRAD test board schematic referenced "TRAD/TA1/I-L/TPS25940ARVCR/WQFN20/MF/2308" is illustrated in Figure 8.

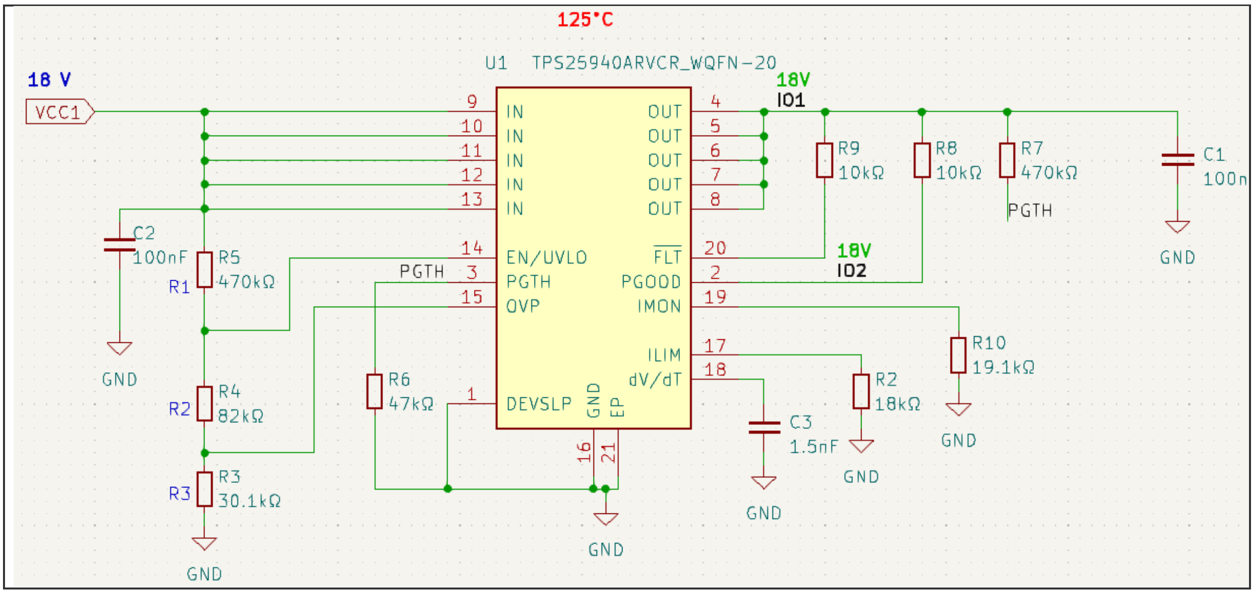

Figure 8: Test board schematic

6.3.4. Test conditions and event detection thresholds

SEL test

	VIN
Voltage	18 V
$I_{nominal}$	<5 mA
$I_{threshold}$	10 mA
T_{hold}	1 ms
$T_{cut\ off}$	7 ms
Temperature	125°C

Table 6: SEL test conditions and detection thresholds

7. Test story

No atypical behaviour during the test to report.

8. Non conformance

Test sequence, test and measurement conditions were nominal.

9. Results

In this chapter are presented the SEE test results.
First, test runs summary tables provides details of the runs performed during this campaign, their parameters and results.
Then, for each event type are given their corresponding LET threshold, cross section and worst cases when it is applicable.
On the cross section curves are plotted their corresponding error bars.
The following formulas is used to calculate these error bars. It can be found in ESCC Basic specification No. 25100.

$$\delta\sigma \times F = \sqrt{(\delta Nevents)^2 + (\mathrm{Nevents} \times \frac{\delta \mathrm{F}}{F})^2}$$

where :

- F is the fluence
- $\sigma = N_{events} / F$
- δF/F is the uncertainty on the measured fluence (±10%).
- δN_{events} is the variance on the measured number of events.

Assuming that SEE events are random, the probability of events follows a Poisson distribution. The variance on the number of events is calculated from the chi-square distribution for a given confidence level. In this test report, we used a confidence level of 95%.

9.1. Test run summary

Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Tilt (°)	Eff. LET (MeV.cm²/mg)	Eff. Range (µm Si)	Flux (φ) (cm^{-2}.s^{-1})	Time (s)	Run Fluence (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	SEL	SEL Cross Section (cm²)	Destrutive Event	Destrutive Event Cross Section (cm²)
1	**SEL**	**1**	**125**	**Ag**	1714	**0**	38.8	158.0	1.13E+03	**6**	**6.80E+03**	0.00	0.00	**0**	<1.47E-04	**0**	<1.47E-04
1	**SEL**	**3**	**125**	**Ag**	1714	**0**	38.8	158.0	1.13E+03	**6**	**6.80E+03**	0.00	0.00	**0**	<1.47E-04	**1**	1.47E-04
2	**SEL**	**1**	**125**	**Fe**	941	**0**	13.3	214.0	8.57E+03	**14**	**1.20E+05**	0.03	0.03	**0**	<8.33E-06	**1**	8.33E-06
2	**SEL**	**4**	**125**	**Fe**	941	**0**	13.3	214.0	8.57E+03	**14**	**1.20E+05**	0.03	0.03	**0**	<8.33E-06	**0**	<8.33E-06

Table 7: TPS25940ARVCR test run table

SEE detailed results are described in the following sections.

9.2. Cumulated dose table

Part No.	Cumulated Dose (krad)
1	0.03
3	0
4	0.03

Table 8: Cumulated dose table

9.3. SEL test results

9.3.1. SEL LET threshold

The SEL test was performed under SEL test conditions (see Table 6).

In SEL test configuration
Destructive events were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET tested during this test campaign.

10. Conclusion

The heavy ions test was performed on TPS25940ARVCR. The aim of the test was to evaluate the sensitivity of the device versus SEL.

The SEL test was performed under SEL test conditions (see Table 6).

In SEL test configuration
Destructive events were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET tested during this test campaign.